

## Introduction

This chapter is intended to be a guide for replicating the results we obtained using the model BurnPro and/or for modeling additional scenarios to explore the effect of alternative fire management strategies. This chapter assumes that the reader has basic GIS and spreadsheet skills. Experience and skill working with fire behavior models and fire weather analyses would also be useful. If the user has no fire-modeling skills s/he will need to familiarize her/himself with the proper use of the software packages used. Substantial preparation of the data is necessary, and involves use of the fire analysis tools FireFamilyPlus and FlamMap. Much of the data referred to accompanies this report and are ready to use. See Appendix...

BurnPro is a GIS model that estimates the annual probability of burning for every pixel on a raster landscape. BurnPro uses topography, historic weather, current fuel model data and historic ignition locations to estimate the likelihood of burning given the speed and direction a fire might spread from any ignition point. It computes the probability of burning a location as the product of the probability that fire reaches the location before the end of the fire season and the probability that fire will reach the location before a fire-stopping event. As such, it integrates the timing and location of ignitions, rate of spread of fire (as it is affected by fuels, topography and weather), length of fire season as it varies over elevation, and frequency of fire-stopping events (i.e., rain) during the fire season.

BurnPro is intended to support long-term processes such as fire management planning. It is not suitable for most incident management applications, but can be useful for the type of pre-planning that supports a go/no-go decision. For more details on BurnPro, please see 'Modeling Wildfire Probability Using a GIS' (Davis, B. and C. Miller. 2004) in Appendix \*

## Software and Hardware requirements

Software Requirements: ArcInfo Workstation, FlamMap, FireFamilyPlus , spreadsheet program like Excel.

Hardware Requirements: Follow the system requirements for ArcInfo Workstation (<http://www.esri.com/software/arcgis/arcinfo/about/systemrequirements.html>) and FlamMap (<http://fire.org/nav.mas?pages=flammap&mode=16>). As always, more is better, especially for large study areas.

## Data Requirements

Before acquiring data it is necessary to define two parameters. First, you must define your *study area* which will likely depend on data availability. Ideally, your GIS data layers will encompass a large buffer (e.g. 10 kilometers) around your true area of interest (e.g., a National Park). In reality, this is very difficult to find, and therefore you should use the maximum buffer possible. Second, you must define the length of your *fire season*. The fire season should be defined in whole months and its length should be the known length at the lowest elevation in your study area (e.g., June-September). Currently the longest fire season that BurnPro accommodates is five months. There are ways to extend this but they are not covered in this guide.

The basic data required to prepare for and to run BurnPro includes:

- historic ignition points
- daily historic weather data from Remote Automated Weather Stations (RAWS) or similar weather stations
- current fuel type data
- topographic data (elevation, slope and aspect)
- boundaries delineating the study site and other areas of interest
- three additional data files (see 'Additional data files' section below).

Each of these data sets is described below and all required data are provided for each of our study areas on the accompanying cd. To apply BurnPro to a different

study site, it may be necessary to acquire new data. Modifying model parameters may also require new data and/or further manipulation.

*General guidelines for all data collection and preparation:*

- attempt to get data that extends beyond the area of interest,*
- resample to **common cell size** (if raster data) and*
- re-project** all data to a common projection*

## Historic Ignition Points (NIFMID/SACS)

### Acquiring historic ignition data

Historic ignition data resides in the National Interagency Fire Management Integrated Database (NIFMID) for USDA Forest Service lands. Historic ignitions for the Department of the Interior lands (NPS, BLM, FWS and BIA) reside in the Shared Applications Computer System (SACS). Ignition data from both of these databases can be obtained from the National Wildfire Coordinating Group's (NWCG) 'Fire & Weather Data' website (<http://famweb.nwcg.gov/weatherfirecd/>).

There are numerous, well-documented shortcomings of these data, many of which you can find outlined in the Program for Climate, Ecosystem and Fire Application's (CEFA) 'Coarse Assessment of Federal Wildland Fire Occurrence Data' (<http://www.cefa.dri.edu/Publications/fireoccurrencereport.pdf>). In addition to this report, CEFA has developed a database of federal ignition points in which some of the grossest errors have been corrected or flagged. The majority of the ignition data used in this project were obtained from this database. To obtain these data, use the contacts listed in the CEFA report.

It is important to have both extensive and accurate records in order to capture historic ignition patterns. In general, locational accuracy of ignition points decreases the further back in time you go. Therefore it is necessary to make a compromise between the number of years of ignition data used and the accuracy of ignition location. For example, in most of our study areas we used 1986

through the most current year available. We chose 1986 as a cut off date because this is the year when many agencies began reporting ignition location as points (latitude / longitude) rather than as within an area (township, range, section). In addition, it is necessary to decide if there is a particular type of ignition you are interested in (e.g. lightning, human-caused or both).

## Preparing historic ignition data

Before they can be input into BurnPro the ignitions of interest must be extracted from the source data and converted into an ArcInfo point coverage. This extraction may include spatially selecting the ignitions of interest (e.g. by clipping them with the study boundary) and/or the selection of the ignitions of interest (e.g. lightning caused ignitions). In addition the ignitions must be separated into month of occurrence, one point coverage for each month in the fire season

## Historic Weather Conditions

### Acquiring historic weather data

Daily weather data are required to develop the information that BurnPro needs on historic weather conditions. Daily weather data can be obtained most easily from the NWCG's website (<http://famweb.nwcg.gov/weatherfirecd/>).

The first step is to select which weather station(s) you want to use. This should be defined by someone familiar with the area and preferably with fire modeling experience (FARSITE, FlamMap etc.). General considerations to keep in mind include selecting stations that are representative of the area as a whole and have complete and extensive records.

The station(s) selected should be elevationally and spatially representative. If you are using one station its elevation should be near the average elevation of the study area, if using more than one station the average elevation of the stations should be near the average elevation of the study area and should have a variety of elevations (e.g. one low, one mid and one high). Better yet, the station(s) should be elevationally near the average elevation of just those portions of the study area that have burnable fuels because those are the areas of interest.

Station selection should also be spatially representative of the study area. In other words, if you are using one station it is preferable to have it located near the center of the study area. If using more than one station, they should be as evenly spread across the study area as possible rather than clumped together.

Stations should also have complete records. There should be no large gaps in the daily records for the months of the fire season. You can look for gaps by opening the weather files in Excel (see below for instructions on manipulating weather data into a format that can be imported into Excel easily) and obtaining record counts by year/month. They should also be as extensive, in terms of length of record, as possible. It is recommended that you use at least 20 years worth of data and definitely no less than 10. The available years for each station are listed on the NWCG website. The goal is to capture the variability in weather conditions for the area in order to predict what might be expected in the future.

Of course locating stations that fit all these requirements exactly would be nearly impossible. But it is important to adhere to them as closely as possible keeping in mind that the further they are deviated from the less accurate the results will be.

Once you have selected your station(s) download the weather files (\*.fwx) and the catalog files (\*.txt) from the NWCG website (or other source).

## Preparing historic weather data

The weather data need to be summarized to provide the information about historic weather conditions required by BurnPro. This information is used to establish the frequency of fire-stopping weather events, determine the frequency distribution of wind directions, and to predict rate of spread of fire.

Fire stopping event frequency. BurnPro requires the average annual number of fire-stopping events for each month in the fire season. A fire-stopping event is defined as the quantity of rain necessary to extinguish or severely curtail the spread of a wildfire. For example, '0.5 inches in 5 days or less' was used for all our study areas except the Great Smoky Mountains National Park. This number was selected based on analysis in 'Probability of Fire-Stopping Precipitation Events' (Latham and Rothermel, 1993) a copy of which can be found in the

appendix. Note that this particular definition may not apply to all study locations and the values chosen should be reflective of local conditions. For example, we used '1.5 inches of rain in 5 days or less' for Great Smoky Mountains National Park based on feedback from local managers.

Wind direction distribution. BurnPro requires information on the historic distribution of wind directions for the study area. This is simply how often the wind blows from a particular direction (e.g. Southwest – 50% of the time, South – 10% etc.).

Weather data for ROS calculations. Finally, historic weather data need to be summarized for FlamMap to calculate the Rate Of Spread (ROS) values that are required by BurnPro. FlamMap's specific requirements for weather data are outlined below in the section on creating FlamMap input files.

## FireFamilyPlus

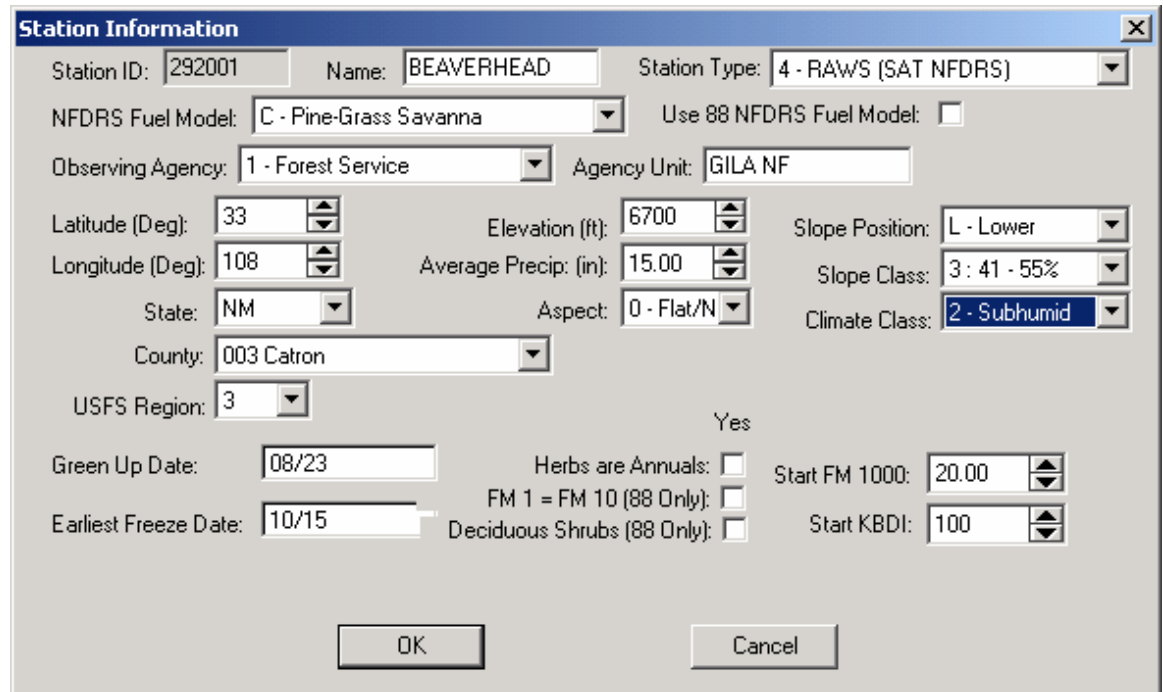
Much of the weather data summarization requires the use of FireFamilyPlus (FFP). FFP is a fire climatology and occurrence program freely available from the fire.org website (<http://fire.org/mason/nav.cgi?pages=ffp&mode=1>). If you are unfamiliar with FFP it is highly recommended that you obtain the users guide and familiarize yourself with its basic operations before proceeding.

### Step One – Load the data.

The following will need to be repeated for each weather station used:

- Import the weather and catalog files into FFP. These files come from the NWCG website or another source.
- Verify that all station information is correct (elevation, location, etc.)
- You can edit the station information via the Station Information dialog box (Figure 3). Green-up and freeze dates are especially important due to their effect on herbaceous fuel moistures.

**Figure 3.** FFP station information dialog box.



The 'Station Information' dialog box contains the following fields and controls:

- Station ID: 292001
- Name: BEAVERHEAD
- Station Type: 4 - RAWs (SAT NFDRS)
- NFDRS Fuel Model: C - Pine-Grass Savanna
- Use 88 NFDRS Fuel Model: ☐
- Observing Agency: 1 - Forest Service
- Agency Unit: GILA NF
- Latitude (Deg): 33
- Elevation (ft): 6700
- Slope Position: L - Lower
- Longitude (Deg): 108
- Average Precip: (in): 15.00
- Slope Class: 3 : 41 - 55%
- State: NM
- Aspect: 0 - Flat/N
- Climate Class: 2 - Subhumid
- County: 003 Catron
- USFS Region: 3
- Green Up Date: 08/23
- Herbs are Annuals: ☐
- Start FM 1000: 20.00
- Earliest Freeze Date: 10/15
- FM 1 = FM 10 (88 Only): ☐
- Start KBDI: 100
- Deciduous Shrubs (88 Only): ☐

Buttons: OK, Cancel

Step Two—Define your ‘Working Set’ (Figure 4).

Set the ‘Data Years’ as desired (e.g. 1985-2003). Then set the ‘Annual Filter’ to the length of the fire season. This will be the known length of fire season at the lowest elevation for the study area and must comprise whole months (e.g. May 1st – September 31st).

**Figure 4.** FFP working set definition.

**FireFamily Plus - [gila.mdb - Working Set]**

File Data Weather Fires Options Window Help

Database Name: C:\Projects\BurnPro\GILA\Weather\gila.mdb

Description: Default Database Structure for FireFamily Plus

Active Working Set Definition

SIG/Station: 292001 - BEAVERHEAD

Data Years (1964 - 2003): 1975 thru 2003

☒ Enable Auxiliary Year Overlays

Analysis Period Length (Days): 1

Annual Filter (Time of Year)

Month: May thru July

Day: 1 thru 31

Fire Associations

SIG/Station Metadata:

StationID	Name	NFDRS Fuel Model	Use 88 Model	Slope Class	Climate Class	Greenup D
292001	BEAVERHEAD	C - Pine Grass Savanna	<input type="checkbox"/>	3	2	08/23

Ready NUM

### Step Three—Extract variables.

The next step is to export the following data via the following menu selections: Weather→ Season Reports→ Daily Listing (Figure 5). This will need to be repeated for each weather station.

Select the following variables for export (in this order):

- Date (Date Format: YYYYMMDD),
- Spread Component,
- Max Temperature,
- Min Temperature,
- Relative Humidity,
- Max Rh,
- Min Rh,
- Wind Speed,
- Wind Direction,



- 1-Hour Fuel Moisture,
- 10-Hour Fuel Moisture,
- 100-Hour Fuel Moisture,
- Herbaceous Fuel Moisture and
- Woody Fuel Moisture.

Uncheck Date/Time stamp, column header and report header. Hit 'OK' and save the resultant 'daily listing' window as a text file.

**Figure 5.** FFP daily listing dialog.

**Select Output Variables for Daily Listing**

**Date Format:**

- ☐ MM/DD/YYYY
- ☐ MMDDYYYY
- ☒ YYYYMMDD
- ☐ MM/DD
- ☐ MMDD

**Time Format:**

- ☐ HH:MM
- ☐ HHMM
- ☒ None

**Fire Outputs:**

- ☐ Number of Fires
- ☐ Number of Large Fires
- Large Fire Day (Acres):
- ☐ Number per Size Class
- ☐ Total Acres

**General:**

- ☐ Report Header
- ☐ Column Header
- ☐ Date/Time Stamp

**Fire Cause Filter:**

- ☒ All
- ☐ Lightning
- ☐ Human

**Available Variables:**

- Buildup Index (CAN)
- Fire Weather Index (CAN)
- Daily Severity Rating (CAN)

**Selected Variables:**

- Spread Component
- Max Temperature
- Min Temperature
- Relative Humidity
- Max RH
- Min RH
- Wind Speed
- Wind Direction
- 1-Hour Fuel Moisture
- 10-Hour Fuel Moisture

Buttons: >>>>, <<<<, Select All, Remove All, OK, Cancel

Step Four—Fire Stopping Events.

The Event Locator in FFP is used to find the occurrences of a fire-stopping event. For most Western US areas this should be around 0.5 inches within a five-day period. Make sure that the 'Annual Filter' in the FFP working set definition window (Figure 4) is set to the length of the fire season. Use: Weather→ Event Locator. The parameters should be set as follows (Figure 6),

- Period length: number of days (e.g. 5),
- Operator: blank,
- Variable: precipitation amount,
- Category: sum,
- Operator: >=,
- Value: inches of rain (e.g. 0.5) and
- Value Type: value.

Hit 'OK' and save the resultant events window as a text file. Repeat for each weather station.

**Figure 6.** FFP event locator.

Event Locator

Period Length (Days):

Enter criteria for event: Use Insert or Down Arrow to add new lines to table

	Operator	Variable	Category	Operator	Value	Value Type
1		Precipitation Amount	Sum	>=	0.50	Value

OK Cancel

Open the fire-stopping event file in a text editor (e.g. notepad) and delete the header, footer and the '/'s from the file (use find and replace for the '/'s). The following is an example of what the cleaned up file should look like (Table 1):

**Table 1.** Fire stopping event file.

DATE	Rain
08251979	0.50
10071981	1.38
09131982	0.56
09201982	0.74
09261982	1.22
...	

## Cleaning Up Weather Data

The following steps will clean up the weather data you just extracted using FFP.

### Step One-Delete blank records:

- Import the 'daily listing' files into a spreadsheet program such as Excel. Choosing fixed width and setting your own delimiters seems to work best (imported columns are right-justified, so set the divider on the right of the column header).
- Look for and delete blank rows in the data. This is important because any sorting you do of the data may only include those rows above the first blank row. The easiest way to accomplish this is to select all data by clicking the area to the left of column A and above row 1 and choose Sort→Ascending, scroll down to the last rows and delete the blank lines.
- Save as an Excel spreadsheet.

### Step Two-Verify weather data:

- Verify the weather data by iteratively sorting all records by *each column*, ascending and descending, and look for missing and/or erroneous data.
- Delete records with missing data *with the exception of maximum and minimum relative humidity*. Maximum and minimum relative humidity are commonly missing and it may be necessary to estimate the missing values later using a technique described below. Therefore *do not delete records on account of missing maximum or minimum relative humidities*. Most of the problem data should be located in the first and last few rows after each sort.

Some common data problems include:  
-missing data,

-wind direction is not zero when wind speed is zero,  
-impossible values (e.g. relative humidities greater than 100%) and  
-improbable data (e.g. temperatures greater than 130 degrees or less than -50 degrees Fahrenheit).

- Basically, look for data that doesn't make sense given your familiarity with the study area.
- Re-sort by DATE ascending when finished verifying data.
- Create a column called YEAR and populate it from the date column using the left function[e.g. LEFT(DATE,4)].
- Create a column called MONTH and populate it from the date column using the left and right functions [e.g. RIGHT(LEFT(DATE,6),2)].

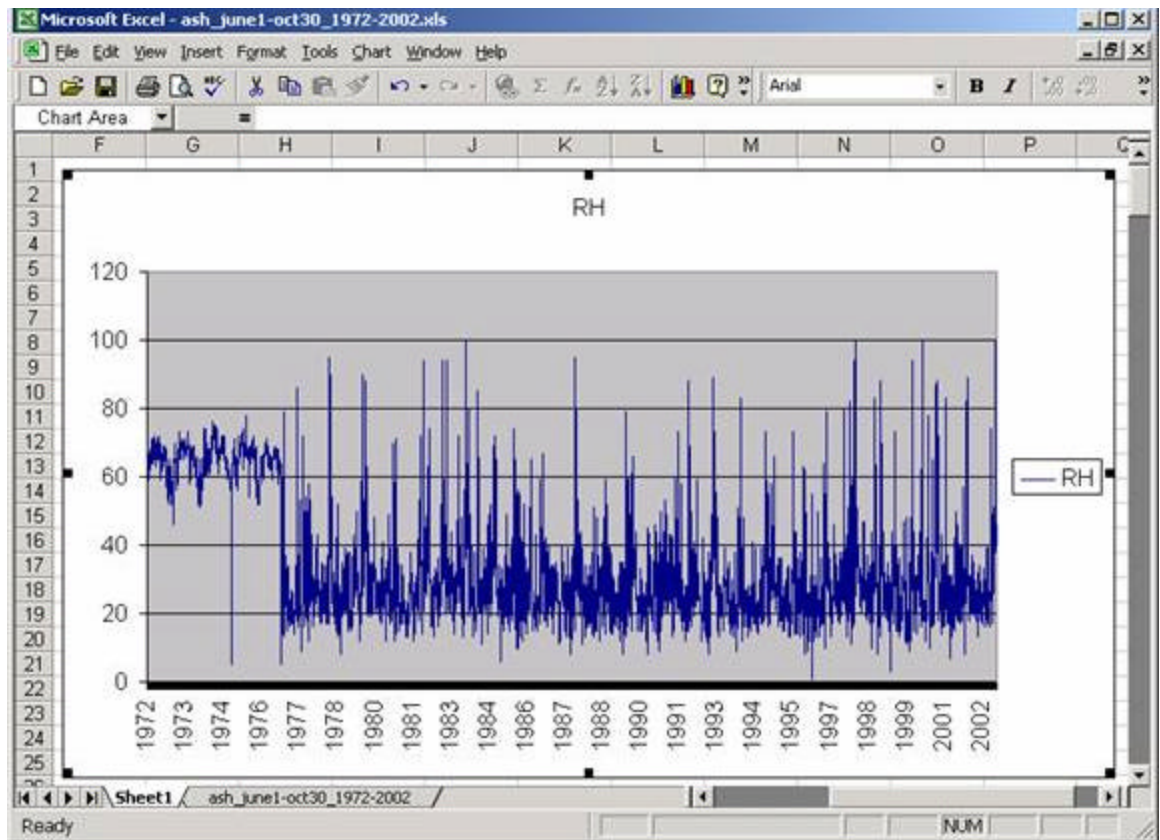
It is a good idea to check whether the numbers of records for each month are in approximately the correct proportion to each other. Missing records are unavoidable but if too many are missing from one month versus the others it will skew the weather calculations. Here's an example:

	<u>Total Records</u>	<u>June</u>	<u>July</u>	<u>August</u>
Station 1	2461	806	816	839
Station 2	2088	452	807	829

Station 1 looks good but station 2 is out of proportion. If the data is used as is the final weather averages will be skewed towards July and August conditions. If you are not comfortable with this then adjustments will be necessary. One possibility would be to separate the data out by month, calculate all averages and average the monthly results together. In this way each month would receive the same weight regardless of the number of records. This technique has not been attempted and therefore there could present unexpected difficulties.

- Create a chart (graph) of YEAR vs. RH to determine whether the methods for data collection have remained the same over the years. It might be wise to do quick eyeball checks of YEAR charted versus other variables to look for other potential errors. In the example shown in figure 7, it is clear that in 1977, something changed in the way RH was collected. Because relative humidity is used to calculate fuel moistures and spread component it is necessary to have consistent collection parameters. Therefore, any data that was apparently collected using different parameters (e.g. the pre 1977 data in Figure 7) should be deleted from your dataset.

**Figure 7.** Graph of relative humidity.



Step Three-estimate missing humidity values.

As mentioned above, minimum and maximum relative humidity values are often missing from the data record. You may decide that without these values, you have insufficient data to summarize. In such cases, it is necessary to estimate the missing values using the relationship between relative humidity (RH) which is the relative humidity gathered at a set time in the afternoon (usually 2-3pm) and each of the relative humidity extremes (maximum and minimum, Rhmax and RHmin) for those records in which all three were collected. In order to do this it is necessary to have at least a few years in which all three variables were collected.

For example:

- Select RH, MxRH and MnRH from those rows that contain maximum and minimum relative humidities and paste them into a new worksheet.

- Add two new columns to the new worksheet called MxRH/RH and MnRH/RH populate them with those ratios (e.g. maximum relative humidity divided by relative humidity).
- Determine the average ratios (e.g. average maximum relative humidity = 2.10 times relative humidity and minimum relative humidity = 0.75 times relative humidity).
- Use these two ratios to populate those MnRH and MxRH cells that have no values in the main worksheet.

Note: It is important that you ensure that these estimates for missing values do not cause maximum relative humidity to exceed 100%. You can ensure this by using an 'IF' statement when calculating maximum relative humidity.  $MxRH = IF(RH * 2.10 > 100, 100, RH * 2.10)$  which, in effect, says "if the ratio times relative humidity is greater than 100 put 100, if not put ratio times relative humidity". Again, we are calculating the missing values because eliminating the records without these values would leave us with too few records. Although it hasn't been tested, it might be possible to increase accuracy of these estimates by calculating the relationship for individual months in the fire season and using these monthly relationships instead to calculate the missing values.

## Summarizing Weather Data: Percentile Categories

Now that the weather data is cleaned up, you are ready to start the process of summarizing it.

### Step One--Defining Percentile Weather Categories

Percentile weather refers to the frequency of occurrence of a particular set of weather conditions in the historical record. In our case Spread Component (SC) defines these weather conditions.

"Spread Component is a numerical value derived from a mathematical model that integrates the effects of wind and slope with fuel bed and fuel particle properties to compute the forward rate of spread at the head of the fire."

"The inputs required to calculate Spread Component are wind speed, slope, fine fuel moisture (including the effects of green herbaceous plants), and the moisture content of the foliage and twigs of living, woody plants." (Schlobohm, 2002)

For example, if you used FFP to calculate SC for a group of 100 weather records and then sorted or ranked the records by SC value, the record ranking 99<sup>th</sup> would be the one whose value for SC was higher than all but one record. This would be the 99th percentile SC. Furthermore, the set of weather conditions that resulted in this 99<sup>th</sup> percentile SC would be the 99th percentile weather conditions. Rather than using percentile weather *conditions*, we elected to use percentile weather *categories*. We determined the weather conditions for each category by taking the average of each weather condition in that percentile category. For example, to determine these conditions for the 99th to 100th percentile weather category we averaged all the weather conditions that resulted in the top 1% of all SCs.

The majority of fire spread occurs under the more extreme weather conditions (low relative humidity, high winds etc.), and concomitantly, under high SC conditions. Therefore, percentile weather categories should be defined with an emphasis on the upper percentiles. We found that four categories are a good compromise between accuracy and processing time. For example, many of our study sites were run with the following percentile weather categories: 0-79, 80-89, 90-97 and 98-100.

BurnPro predicts *average* annual probability of burning and therefore defining narrow upper percentile categories does not mean that the results are being skewed towards the more extreme conditions. BurnPro performs a weighted average of the probability predictions resulting from each percentile category. The weights given to each prediction are based on the size of the percentile weather category, where the 0-79 category is 8 times "larger" than the 80-89 category. For example, if the probability of burning for a particular place on the landscape was 0.10 for the 0-79 category, 0.20 for the 80-89 category, 0.40 for the 90-97 category and 0.80 for the 98-100 category, the average annual probability prediction would be  $(0.10 * 0.80) + (0.20 * 0.10) + (0.40 * 0.07) + (0.80 * 0.02) = 0.144$ .

## Step Two--Calculating Average Percentile Weather Conditions

Next, it is necessary to determine the average weather conditions that represent each of the percentile categories.

- Sort the data by SC descending.
- Determine spread component percentile cutoffs using Excel's PERCENTILE function which is of the form: PERCENTILE(Array,k). Where Array is the range of SC values and k is the percentile of interest. For example,

PERCENTILE(A2:A3000, 0.99) would calculate the 99<sup>th</sup> percentile SC for the range of SCs found in cells A2 through A3000.

- Use the inclusive cutoffs to obtain subtotals (average function) for the following variables: maximum temperature, minimum temperature, relative humidity, maximum relative humidity, minimum relative humidity, all five fuel moistures categories and wind speed. For example, if one of your percentile weather categories was 0-79, and you calculated the 79<sup>th</sup> percentile SC = 5, you would need to calculate the average temperatures, humidities, fuel moistures and wind speeds for those records with a SC between 0 and 5.
- Copy all the average results to a new “RESULTS” worksheet.
- Clear the average subtotals.
- Obtain overall counts (using subtotals with the count function) of each wind direction and calculate the percentage that they represent. For example, if 4000 of 8000 records indicate southwest winds then winds are out of the southwest with a frequency of 0.50 (50% of the time). It is necessary to use the count function rather than the average function because wind is a discrete rather than continuous variable.

Note: wind direction value of 0 = calm, 1 = NE, 2=E, 3=SE, 4=S, 5=SW, 6=W, 7=NW, 8 = N.

- Copy the wind direction count results to the RESULTS worksheet.
- Repeat the above processes for each weather station.
- Calculate the average values across weather stations (see Table 2 for an example).

**Table 2.** Average weather conditions by percentile weather conditions.

[illegible]



75.72	35.12	17.50	65.05	14.04	21.26	3.56	5.52	9.70	3.56	60.00	98-100
79.40	35.89	17.72	67.08	14.23	14.60	3.59	5.50	9.35	3.59	60.00	90-97
81.00	37.73	17.34	64.51	13.72	10.64	3.53	5.34	8.69	3.53	60.00	80-89
81.40	43.66	27.28	76.81	20.99	5.58	5.92	9.92	10.85	5.92	60.00	0-79

Station 3  
5600ft

84.24	37.06	17.24	56.01	12.15	21.57	3.26	4.33	9.94	3.26	50.93	98-100
84.59	36.93	14.96	49.34	10.56	14.33	3.01	5.03	8.42	3.01	52.48	90-97
86.10	37.98	14.89	49.36	10.46	11.08	3.08	5.14	8.34	3.08	52.97	80-89
86.64	43.88	29.51	75.97	20.64	5.32	5.77	8.55	12.10	5.77	51.63	0-79

Average  
(7418ft)

<b>74.49</b>	<b>37.43</b>	<b>15.73</b>	<b>48.77</b>	<b>11.73</b>	<b>17.16</b>	<b>3.09</b>	<b>4.23</b>	<b>8.13</b>	<b>3.09</b>	<b>56.98</b>	<b>98-100</b>
<b>79.74</b>	<b>39.55</b>	<b>14.89</b>	<b>49.38</b>	<b>11.55</b>	<b>11.48</b>	<b>2.96</b>	<b>4.50</b>	<b>7.46</b>	<b>2.96</b>	<b>57.49</b>	<b>90-97</b>
<b>81.37</b>	<b>40.80</b>	<b>15.64</b>	<b>50.11</b>	<b>11.94</b>	<b>8.55</b>	<b>3.11</b>	<b>4.60</b>	<b>7.49</b>	<b>3.11</b>	<b>57.66</b>	<b>80-89</b>
<b>81.58</b>	<b>45.62</b>	<b>30.05</b>	<b>72.11</b>	<b>21.94</b>	<b>4.23</b>	<b>6.03</b>	<b>8.60</b>	<b>10.86</b>	<b>6.03</b>	<b>57.21</b>	<b>0-79</b>

Wind Direction	Station 1	Station 2	Station 3	Average
North	0.15	0.12	0.05	<b>0.11</b>
Northeast	0.12	0.07	0.06	<b>0.08</b>
East	0.07	0.09	0.03	<b>0.07</b>
Southeast	0.12	0.19	0.15	<b>0.15</b>
South	0.15	0.21	0.24	<b>0.20</b>
Southwest	0.15	0.14	0.30	<b>0.20</b>
West	0.11	0.08	0.11	<b>0.10</b>
Northwest	0.11	0.10	0.06	<b>0.09</b>

With the exception of wind direction, all values will be used to create input files for FlamMap. The wind direction information will be input into BurnPro directly.

## Create FlamMap Input Files

The average values for the weather percentile categories will be used to create the following FlamMap input files: initial fuel moisture (.FMS) files, weather (.WTR) files and wind (.WND) files. *One of each will be created for each percentile weather category.* The .WTR and .WND files are used to condition the initial fuel moistures. In other words, FlamMap sets the initial fuel moistures according to the .FMS file and then simulates what they would change to after being exposed to the conditions in the weather and wind files. With conditioning, FlamMap calculates "...dead fuel moistures for each cell based on topography, shading, weather and conditioning period length" (FlamMap, 2004)

Use a text editor (e.g. notepad) to create the files following these formats (see either FlamMap or FARSITE help for more information on these files (FlamMap, 2004). Be sure to name the files with the proper extension (.fms, .wtr or .wnd)

Fuel Moisture File Format:

***FuelMod 1Hour 10Hour 100Hour LiveH LiveW***

Repeat with same values for all fuel types represented in your fuels data. E.G.

```
1 3 5 7 8 60
2 3 5 7 8 60
4 3 5 7 8 60
5 3 5 7 8 60
6 3 5 7 8 60
8 3 5 7 8 60
9 3 5 7 8 60
10 3 5 7 8 60
11 3 5 7 8 60
12 3 5 7 8 60
13 3 5 7 8 60
14 3 5 7 8 60
18 3 5 7 8 60
28 3 5 7 8 60
```

Weather File Format:

***Month Day Precip Hour1 Hour2 MinTemp MaxTemp MaxRh MinRh Elev***

Always place zeros under Precip. Hour1 is the time of the minimum temperature and Hour2 is the time of the maximum temperature. Elevation should be the average elevation of the weather stations. Repeat for the number days you want to condition the fuels before running FlamMap. It is recommended that you condition fuel moistures for three to five days. The actual dates used are irrelevant as long as they are consecutive. E.G.

```
7 1 0 0500 1500 70 98 49 20 4433
7 2 0 0500 1500 70 98 49 20 4433
7 3 0 0500 1500 70 98 49 20 4433
7 4 0 0500 1500 70 98 49 20 4433
7 5 0 0500 1500 70 98 49 20 4433
```

Wind File Format:

### ***Month Day Hour Speed Direction CloudCover***

The development of this file requires some compromises and approximations. Use the same days as the weather files and four-hour intervals. Of those four-hour intervals put your desired wind speed in the 1200 and 1600 intervals and put zeros in the rest. Your direction will always be the most prevalent direction for the study area e.g. 225 (SW). Populate cloud cover with zeros. This file needs to have units defined on first line (English vs Metric) E.G.

```
ENGLISH
7 1 0000 0 225 0
7 1 0400 0 225 0
7 1 0800 0 225 0
7 1 1200 15 225 0
7 1 1600 15 225 0
7 1 2000 0 225 0
7 2 0000 0 225 0
7 2 0400 0 225 0
7 2 0800 0 225 0
7 2 1200 15 225 0
7 2 1600 15 225 0
7 2 2000 0 225 0
.
.
.
7 5 0000 0 225 0
7 5 0400 0 225 0
7 5 0800 0 225 0
7 5 1200 15 225 0
7 5 1600 15 225 0
7 5 2000 0 225 0
```

Repeat the creation of these files for each percentile weather category.

### **Frequency of a Fire-Stopping Event**

To determine the frequency of a fire-stopping event, open the fire-stopping event file in Excel, making sure to *import the date column as text*. Sort by date and compute subtotals (counts) for each month. Also note the period of record (i.e., number of years) for each station.

Because these subtotals represent counts of a discrete event (e.g., x inches of rain within a y-day period) they will be distorted by any missing records We want

to give each station equal weight when calculating the monthly fire-stopping event probabilities. Therefore, it may be necessary to adjust the frequency calculation.

Consider the following example:

**Table 3.** Fire stopping event frequency data.

<u>Station 1</u>					
	<u>records</u>	<u>days</u>	<u># yrs</u>	<u>events</u>	<u>pstop</u>
May	300	31	9.68	2	0.21
June	292	30	9.73	10	1.03
July	287	31	9.26	21	2.27

<u>Station 2</u>					
	<u>records</u>	<u>days</u>	<u># yrs</u>	<u>events</u>	<u>pstop</u>
May	806	31	26.00	11	0.42
June	816	30	27.20	12	0.44
July	839	31	27.06	59	2.18

<u>Station 3</u>					
	<u>records</u>	<u>days</u>	<u># yrs</u>	<u>events</u>	<u>pstop</u>
May	827	31	26.68	10	0.37
June	800	30	26.67	15	0.56
July	830	31	26.77	60	2.24

The fire-stopping event probability is being calculated based on three weather stations, Station 1, Station 2 and Station 3. In the table 'records' represents the number of records present for that station/month, 'days' equals the number of days in the month, '# yrs' is the standardized number of years that number of records represents (calculated by dividing 'records' by 'days'), 'events' is the number of times the fire-stopping event occurred within the records (calculated by FFP) and 'pstop' is the frequency of the fire-stopping event (calculated by dividing 'events' by '# yrs'). The calculation of 'pstop' is where the weighing to account for missing records is implemented. The final step is to calculate the average pstop amongst the stations (Table 4).

**Table 4.** Fire stopping events.

	<u>Station 1</u>	<u>Station 2</u>	<u>Station 3</u>	<u>Average</u>
May	0.21	0.42	0.37	<b>0.33</b>
June	1.03	0.44	0.56	<b>0.68</b>
July	2.27	2.18	2.24	<b>2.23</b>

These average values will be directly input into BurnPro.

## Current Fuels

The most current fuels data should be obtained for the study site (from the National Forest, Park etc). Fuels should be classified according to Northern Forest Fire Laboratory (NFFL) standards. If the fuels data contains custom fuel models, be sure to obtain their definitions. If at all possible, obtain the 'optional' canopy data (stand height, crown bulk density, crown base height). The canopy data can enhance the accuracy of FlamMap's, and subsequently BurnPro's, predictions.

The fuels data need to be manipulated into the ASCII format for input into FlamMap. This process involves converting all the various fuels data layers (fuel, canopy data) as well as topography data (elevation, aspect and slope). How this is achieved depends on the format in which the original data were acquired. For example, if your fuels data is an ArcInfo grid, you can use the 'gridascii' command to convert it into an ASCII file. It is important to ensure that the original files have *a common projection, format, cell size and origin* (the same minimum X and Y coordinates) before converting them to ASCII files. It is a very good idea to have all these inputs in your desired working cell size (the cell size you want to run BurnPro for) before exporting them to ASCII files.

## Topography

Elevation, slope and aspect data are required to run BurnPro. Topography data can be obtained from various sources including the study site and the National Elevation Dataset (NED) <http://seamless.usgs.gov/viewer.htm> (use the download option). Once you obtain the elevation dataset it can be used to create the slope and aspect data using ArcGIS. These data should be manipulated into the ASCII format and loaded into the landscape file as outlined above for fuels.

## Boundaries

Any boundaries of interest, including your analysis area boundary, should be obtained from the study site (National Forest, Park etc.) and typically need no particular manipulation. Examples include: Wilderness, Forest, Park, Fire

Management Zones/Units, etc. These boundaries are used to define study areas (e.g., buffer the area of interest) and to manipulate (e.g., clip) ignition and fuels data.

## Additional data files

There are three additional files that are necessary to run BurnPro.

The first file is maxrodir.rmt. This is a generic remap table that groups 360-degree aspects into eight categorical directions (e.g. North, Northeast, etc.). It allows BurnPro to classify the direction of maximum fire spread predicted by FlamMap into eight categories.

The two other files are sigma.rmt and eta.rmt. These files contain information about the length of fire season over elevation. They are specific to each individual study site and should only be used for that study site, or one with similar characteristics in terms of location and elevation range. Although it is common knowledge that high elevation sites have a much shorter fire season than low elevation sites, to our knowledge, this information does not exist in empirical form. Therefore, we derived this information for each of the study sites. We derived this information by fitting the number of drought-days predicted by the forest dynamics model FACET to the Weibull probability distribution function as described in Miller, C. 2003a. The two files contain the Weibull parameters resulting from that curve fitting exercise. The forest dynamics model FACET was used to calculate the number of drought-days for a range of elevations. This allowed us to develop a relationship between elevation and the number of drought-days, which we used as a proxy for how the length of fire season varies over elevation. Finally, we calibrated this relationship to the maximum length of the fire season (i.e., the length of fire season at the lowest elevation in the study site). We expect to eliminate the use of FACET in the future in favor of a simpler procedure that can be readily implemented by the user.

## Running FlamMap

To run BurnPro, you need to generate two fire-behavior data sets with FlamMap.

First obtain the latest version of the software:

<http://fire.org/nav.mas?pages=flammap&mode=12>

The two fire-behavior datasets to be generated are Rate Of Spread (ROS) and Maximum Spread Direction (MSD). Multiple sets of these data need to be created for many combinations of input parameters and will therefore require a substantial amount of time. For example, if you have defined four weather percentile categories, you will run FlamMap 64 times: 4 (weather percentile categories) X 8 (wind directions) X 2 (times of day – 4am & 2pm) = 64 runs. Depending on the speed of your computer and how vigilant you are during the process, this can take 4-8 hours (or more). As mentioned earlier, it is important that you have a basic familiarity with FlamMap. If you don't, it is highly recommended that you use the tutorial provided with the software to gain that familiarity before proceeding.

### Create and Load the Landscape File

Create the landscape file using FlamMap (File → Create landscape (LCP) files...). Use the ASCII files you created from the fuels and topography data. Refer to the example in Figure 8.

**Figure 8.** FlamMap landscape file generation dialog.

**Landscape (LCP) File Generation**

Load Source LCP File: C:\Projects\BurnPro\GILA\FlamMap\gila.LCP    Clear Fields    Save as LCP    Help

**General**

Latitude: 33    Grid Distance Units: Meters    Rows: 1976    Lower Left X: 663030    CellSize: 90    Columns: 2307    Lower Left Y: 3594030

**Required Themes**

	Source	Use LCP	Source Units	Constants
Elevation:	C:\Projects\BurnPro\...\elv_m.asc	<input type="checkbox"/>	Meters	<input type="checkbox"/> Constant: 0
Slope:	C:\Projects\BurnPro\...\slp_deg.asc	<input type="checkbox"/>	Degrees	<input type="checkbox"/> Constant: 0
Aspect:	C:\Projects\BurnPr...\asp_deg.asc	<input type="checkbox"/>	Degrees	<input type="checkbox"/> Constant: 0
Fuel Model:	C:\Projects\BurnPro...\fm_cust.asc	<input type="checkbox"/>	Custom	<input type="checkbox"/> Constant: 1
Canopy Cover:	C:\Projects\BurnPr...\cc_prcnt.asc	<input type="checkbox"/>	Percent	<input type="checkbox"/> Constant: 50

**Crown Fuels**

Include Crown Fuels: ☒

Stand Height:	C:\Projects\BurnPro\...\sth_m.asc	<input type="checkbox"/>	Meters	<input type="checkbox"/> Constant: 15
Canopy Base Height:	C:\Projects\BurnP...\cbh_mx10.asc	<input type="checkbox"/>	Meters*10	<input type="checkbox"/> Constant: 1
Canopy Bulk Density:	C:\Projects\...\cbd_kgm3x100.asc	<input type="checkbox"/>	kg/m3*100	<input type="checkbox"/> Constant: 0.2

**Ground Fuels**

Include Ground Fuels: ☐

Duff Loading:	NA	<input type="checkbox"/>	Mg/Ha	<input type="checkbox"/> Constant: 50
Coarse Woody Fuels:	NA	<input type="checkbox"/>	Class	<input type="checkbox"/> Constant: 50

Description

Be sure to set the latitude of your study area and make sure all 'Source Units' are correct. As mentioned earlier, some crown fuels layers are optional but they will improve FlamMap's predictions. Ground fuels are not necessary. Load the landscape file into FlamMap (Theme → FARSITE landscape file).

### Set FlamMap Options

Next, set the following default options (Set Options → Preferences → Edit Preferences). Under the Max Spread Direction tab set units to degrees, decimals to 0 and number of classes to 9. It is especially important to make sure that maximum direction values are in degrees. If this option is set to radians it will result in erroneous outputs from BurnPro. Under the Rate of Spread tab set units



to meters per minute (m/min). Once again, Other units will result in erroneous results.

## FlamMap Runs

Once the preferences are set it is time to set up the first FlamMap run (Analysis Area → New Run or double-click 'run' in the left-hand pane). You will set up one run for each percentile weather category you are using. Set the following parameters: Name the run with the percentile weather category it represents. Load the appropriate fuel moisture file. If you are using any custom fuel types load your fuel model definition (.fmd) file (see FlamMap help for more information on .fmd files). Select the 'Wind Direction' radio button. Enter the average wind speed that you calculated above for this percentile weather category. Set the azimuth to 0. (Wind direction azimuth is the from direction e.g. an azimuth of 0 means the winds are coming from the north and an azimuth of 180 means the winds are coming from the south.) Select the 'Use Fuel Moisture Conditioning' radio button and load the appropriate weather and wind files. The 'Fuel Moisture Conditioning Period' Start and End dates will be the first and last days that were entered in the weather and wind files above. The actual dates are irrelevant but your conditioning period should be around five days. The end time is important. We will use two different end times for our Rate of Spread calculations, 2pm and 4am. BurnPro uses the results at these two times to determine average daily rates of spread. Set the conditioning period end time to 2pm (1400) for now.

Below is an example of how to populate the variables this example is for a 0-15 percentile weather category, north winds, 2pm case (Figure 9).

**Figure 9.** FlamMap run definition dialog part 1 .

Run: 0-15

Inputs Outputs

Run Name: 0-15

Fuel Moisture Files

Fuel Moisture File (\*.fms): C:\Projects\BurnPro\SEKI\fla...\0-15.fms

☒ Use Custom Fuels (\*.fmd) C:\Projects\Bu...\SSGIC\_CustomFuel.fmc

Winds

☐ Wind Blowing Uphill Wind Speed (MPH @ 20'): 4

☒ Wind Direction Azimuth (Degrees): 0

☐ Wind Grids

Direction

Speed

Canopy Characteristics

Height(m): 15 Crown Bulk Density(Kg/m3): 0.2

Crown Base Height(m): 5 Foliar Moisture Content (%): 100

Fuel Moisture Settings

☐ Use Fixed Fuel Moistures from Fuel Moisture File

☒ Use Fuel Moisture Conditioning

Weather File (\*.wtr): C:\Projects\BurnPro\SEKI\flammap...\0-15.wtr

Wind File (\*.wnd): C:\Projects\BurnPro\SEKI\flam...\0-15.WND

Fuel Moisture Conditioning Period

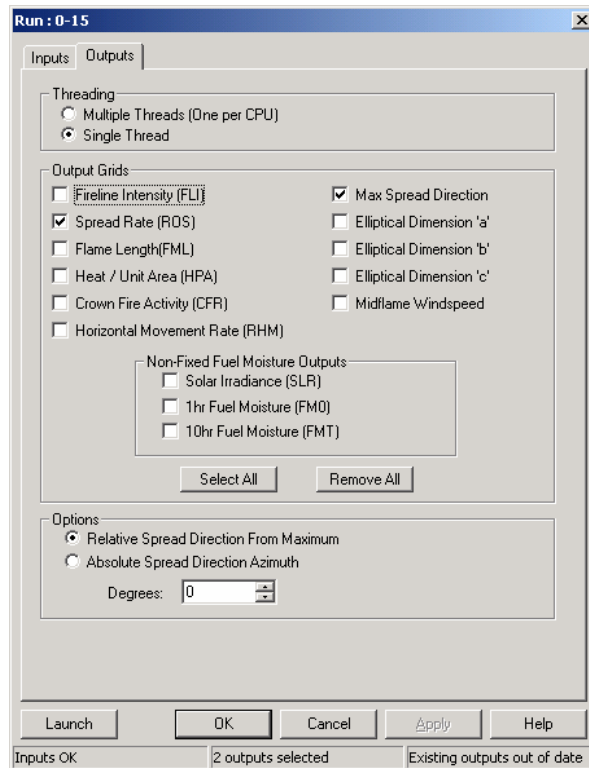
	Day	Time
Start	7/ 2/2004	2:00:00 PM
End	7/ 8/2004	2:00:00 PM

Launch OK Cancel Apply Help

Inputs OK 2 outputs selected Existing outputs out of date

That completes our 'Inputs' definitions. Click on the 'Outputs' tab to define the outputs. Choose Spread Rate (ROS) and Max Spread Direction (MSD). Note that you only need to check the Max Spread Direction box for the 2pm runs. MSD is not calculated for the 4am runs. See the example below (Figure 10).

**Figure 10.** FlamMap run definition dialog part 2.



Once all the parameters for the run have been defined hit the apply button and then the launch button. Once the program is finished running take a look at the results. Double click on each of the two results in the right-hand pane to make sure they are in the correct units (degrees for MSD and meters per minute for ROS). Oddly enough the MSD legend is often displayed in radians (1-6) even though the units indicate degrees. After the MSD data has been exported you can open it in a text editor to ensure it is in the correct units. If you see values greater than six you should be ok. You should only need to perform the unit verification once. To export these files, right click on the ROS and MSD results and save them as .asc files. The outputs need to be named exactly as follows:

Max Spread Direction: maxdir\_<dir><ptile>.asc where <dir> is wind direction (n, ne, e, se, s, sw, w, or nw) and ptile is the upper end of the percentile weather category. For the above example the file name would be: maxdir\_n15.asc

Rate of Spread: ros<ptile><dir><time>.asc where time is the end time of the fuel conditioning period (either 2pm or 4am) For the above example the file name would be: ros15n2pm.asc

You will need to repeat the FlamMap runs for each of the following eight wind direction azimuths: North = 0 (done), Northeast = 45, East = 90, Southeast = 135, South = 180, Southwest = 225, West = 270 and Northwest = 315.

Once the 2pm runs are finished you will need to make the 4am runs for the same eight wind directions. Simply change the end time for the fuel conditioning period to 4am (0400), uncheck the Max Spread Direction box under outputs and make the runs for each of the same eight wind directions.

At this point you should have 16 ROS files and 8 MSD files. Create a new run with the appropriate settings and files for each of your remaining percentile weather categories.

It is a good idea to import a couple ROS files as Grids and check the max values in order to verify that they are in meters per min. As mentioned above, you should check the MSD files by opening them with a text editor to make sure they are in degrees and not radians.

## The Horizontal Factor (HF) Adjustment

FlamMap calculates ROS for the direction of maximum spread (heading direction), but fire travels in other directions (backing and flanking) at lesser rates of spread as well. BurnPro needs information on ROS to find the quickest or shortest path for fire spread but this path may not always be in the direction of maximum spread. Therefore, we need to determine these rates of spread in other directions--this is where the maximum spread direction (MSD) outputs come into play. We use this FlamMap output along with a table of horizontal relative moving angles (HRMA) to estimate these lesser rates of spread. The magnitude of the adjustment is largely dependent on wind speed. Our next step is to create a

HRMA table for each of our percentile weather categories. The HRMA table is contained in a simple text file of which this is an example:

**Table 5.** HRMA adjustment factors.

HRMA (in degrees)	HF
0	1.00
45	1.25
90	1.50
135	1.75
180	2.00

An alternative approach to calculating ROS in non-maximum directions of travel would be to have FlamMap output ROS in each of the eight cardinal directions for each combination of wind direction, percentile weather condition and two times of day. This would have necessitated 512 FlamMap runs versus the 64 currently calculated, greatly increasing the amount of labor involved in the data preparation. In addition, BurnPro's already lengthy processing time would be increased by a factor of eight. The HRMA approach is a compromise between accuracy and processing time.

BurnPro converts ROS into time by taking the inverse of ROS. For example, if you have a ROS of 0.5 meters per minute the inverse would be  $1 \div 0.5 \text{ m/min} = 2.0 \text{ minutes per meter}$ . In other words it takes 2.0 minutes for fire to travel one meter in that cell. As mentioned above, this rate of spread applies to the direction of maximum spread. To determine how quickly fire travels in other directions we multiply it by the horizontal factor. Returning to the example in the HRMA table above, an HRMA of zero indicates the direction of maximum travel and means that the time it takes to travel a meter equals  $2.0 \text{ min/m} \times \text{a HF of } 1.00 = 2.0 \text{ min/m}$ . If BurnPro wants to know how fast fire travels at a right angle (90 degree HRMA) to the maximum spread direction it would multiply  $2.0 \text{ min/m} \times 1.5 \text{ (HF)}$  which equals  $3.0 \text{ min/m}$  and in the opposite direction of the maximum spread:  $2.0 \text{ min/m} \times 2.00 = 4.0 \text{ min/m}$ . To help clarify the point here is a table of the time it takes to travel a meter for various directions when the ROS is 0.5 meters per minute (time = 2.0 minutes per meter) and direction of maximum spread is due North (0 degrees):

**Table 6.** HRMA adjustment factor application

<u>Direction</u>	<u>HRMA</u>	<u>HF</u>	<u>Time (min)</u>
North	0	1.00	2.0
Northeast	45	1.25	2.5

East	90	1.50	3.0
Southeast	135	1.75	3.5
South	180	2.00	4.0
Southwest	135	1.75	3.5
West	90	1.50	3.0
Northwest	45	1.25	2.5

Horizontal factor varies in magnitude with wind speed and slope (Anderson, 1983 and Fons, 1946). The greater the wind speeds the larger the horizontal factors. Therefore, BurnPro requires a separate HRMA table for each of your percentile weather categories because the wind speeds vary with percentile weather category. (Note: The average wind speed you calculated for each percentile weather category are 20 foot wind speeds) An Excel spread sheet has been provided to calculate the horizontal factors for you. The following (Table 7) is an example of those calculations (low weather percentile category average wind speed = 4 mph, moderate = 6 mph, high = 10 and extreme = 15) taken directly from that spreadsheet.

**Table 7.** Horizontal factor calculation.

For 20' Wind speeds between 0 and 7.33 mph:

<i>20' Wind</i>	<i>M-F Wind</i>	<i>HF 45</i>	<i>HF 90</i>	<i>HF 135</i>	<i>HF 180</i>
4	1.2	1.337	1.720	1.976	2.118
6	1.8	1.506	2.080	2.463	2.676
	0	0.000	0.000	0.000	0.000

For 20' Wind speeds between 7.33 and 14.33 mph:

<i>20' Wind</i>	<i>M-F Wind</i>	<i>HF 45</i>	<i>HF 90</i>	<i>HF 135</i>	<i>HF 180</i>
10	3	1.792	2.657	3.293	3.635
	0	0.000	0.000	0.000	0.000

For 20' Wind speeds between 14.33 and 21.33 mph:

<i>20' Wind</i>	<i>M-F Wind</i>	<i>HF 45</i>	<i>HF 90</i>	<i>HF 135</i>	<i>HF 180</i>
15	4.5	2.147	3.364	4.333	4.821
	0	0.000	0.000	0.000	0.000

M-F wind stands for mid-flame wind speed and is calculated from a standard ratio between 20' and mid-flame wind speeds. Create one HRMA table for each percentile weather category. Be sure to use the correct section of the worksheet depending on the 20-foot wind speed you are entering (e.g. a wind speed of 10

mph goes into the “For 20' Wind speeds between 7.33 and 14.33 mph” section). Use a text editor such as notepad to create the HRMA tables. So for the low category (4 mph winds) the HRMA text file should contain the following and nothing else:

**Table 8.** HRMA text file example.

<b>0</b>	<b>1.000</b>
<b>45</b>	<b>1.337</b>
<b>90</b>	<b>1.720</b>
<b>135</b>	<b>1.976</b>
<b>180</b>	<b>2.118</b>

It is important that you name these files exactly as follows: hrma<ptile>.tbl. Where ptile is the upper end of the percentile category. E.g. 'hrma80.tbl' and 'hrma100.tbl'

## BurnPro

Now you are ready to actually run BurnPro!

### Running BurnPro

BurnPro is an ArcInfo AML (Arc Macro Language) program that requires the use of ArcInfo Grid functions and therefore must be run from a Grid prompt. Make sure you have the following files, grids, coverages and data:

- Application files: Burnpro10.aml, burnpro10\_1.menu, burnpro10\_2.menu and makedens.menu
- One ignition point coverage for each month in the fire season.
- Rate of Spread ASCII files (if you are using four percentile weather categories there should be 64 of these)
- Maximum Spread Direction ASCII files (if you are using four percentile weather categories there should be 32 of these)
- Elevation grid
- One HRMA file for each percentile weather category
- Remap tables: Maxromdir.rmt, Sigma.rmt, Eta.rmt

- The fire-stopping event probabilities (one per month).
- Wind direction distributions (eight wind directions)

**Tip:**

It is a good idea to reboot your computer immediately before running BurnPro.

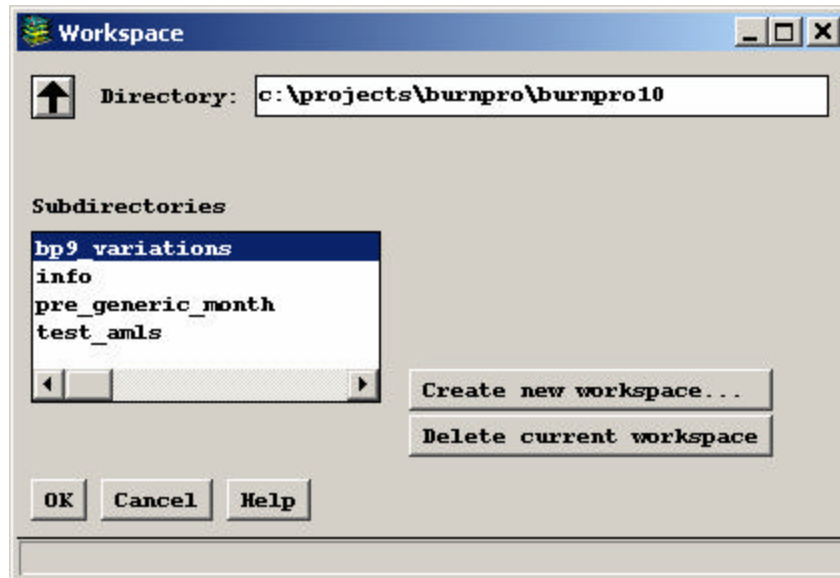
BurnPro can take a very long time to run for large data sets. The biggest influences on run-time are the number of percentile weather categories, the size of the study area in terms of the number of cells in your input grids and the number of ignitions in the monthly ignition grids. Checking the number of rows and columns in your elevation grid will give you some idea of how long the process will take. An area with grid size 1700 X 1300 (90 meter cells) and approximately 2500 ignitions required about 24 hours to run on a 2.0 GHz Pentium 4 with 1 Gb RAM. An area with 800 X 1300 cells and 1700 ignitions required 8 hours. An area with 600 X 800 cells and 34 ignitions required 3 hours.

The BurnPro AML and menu files must be located in the same workspace. The remaining data should also be located in a common workspace but it can (and should) be a different workspace than the program files. Once you have all the necessary data located in a single workspace, start ArcInfo, navigate to the workspace where burnpro10.aml is located, start Grid and type &r burnpro10.

The first menu you encounter will be this:

**Figure 11.** BurnPro workspace menu.





Use it to navigate to where your input data is located (note: your workspace should already be created and populated with all the necessary data. Therefore you shouldn't be creating new workspaces with this menu). Once you do this BurnPro will ask you for the number of months in the fire season and if you need to create ignition density grids:

**Figure 12.** BurnPro input menu 1.

The image shows a Windows-style dialog box titled "Form". It has a blue title bar with a small icon on the left and standard window controls (minimize, maximize, close) on the right. The main area of the dialog contains the text "Enter the number of months in the fire season" followed by a text input box containing the number "5". Below this, there's another line of text: "Do you need to create ignition density GRIDS?". At the bottom of the dialog are two buttons: "Yes" and "No".

Enter the number of months and choose 'Yes' for the density grid question.

At this point the following screen should appear.

**Figure 13.** BurnPro input menu 2.

**Form**

Select the ignition point coverages

Month 1	c:\projects\burnpro\gsm\analysis\sltng_w\apr86021t_z23
Month 2	c:\projects\burnpro\gsm\analysis\sltng_w\may86021t_z23
Month 3	c:\projects\burnpro\gsm\analysis\sltng_w\jun86021t_z23
Month 4	c:\projects\burnpro\gsm\analysis\sltng_w\jul86021t_z23
Month 5	c:\projects\burnpro\gsm\analysis\sltng_w\aug86021t_z23
Month 6	

Select the elevation grid

Elev c:\projects\burnpro\gsm\analysis\sltng\_w\elv90m

17 Enter the number of years represented in the ignition data

1 Enter the ignition density cutoff value

90 Enter the desired cell size

4 Enter the number of percentile weather categories

Enter the upper percentile for each weather category seperated by a single space

79 89 97 100

Enter the fire-ending event probabilities for each month

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
1.72	1.49	1.90	1.48	0.98	

Enter the wind direction distributions (e.g. 50 percent = 0.50)

N	NE	E	SE	S	SW	W	NW
0.02	0.06	0.04	0.08	0.14	0.28	0.35	0.03

OK Cancel

Note: Due to an odd glitch it is necessary to populate the text boxes before selecting the ignition point coverages or the elevation grid.

- Enter the number of years you used in your ignition data.
- Always enter "1" for the cutoff value.
- Enter your desired cellsize. BurnPro will resample any grids not in this cell size (including the ROS and MSD data which will be imported as grids from the ASCII files). It is a very good idea to already have your data in the desired cellsize, as this process can take a lot of time. This includes all the fuels and topography data you used to create the landscape file for FlamMap.

- Enter the number of percentile weather categories (e.g. 4)
- Enter the upper percentile for each weather category (e.g. 79 89 97 100) The last value will always be 100.
- Enter the fire-stopping event probabilities you calculated above in chronological sequence (e.g. Month 1 = May, Month 2 = June, Month 3 = July, etc.).
- Enter the wind direction distributions (e.g. 50% = 0.50)
- Select your ignition grids in chronological order using the 'Month X' buttons
- Select your elevation grid using the 'Elev' button.
- Verify all your entries.
- Hit ok and go have a sandwich... or a nap... or a weekend...

## BurnPro Results

BurnPro outputs the following ArcInfo grids:

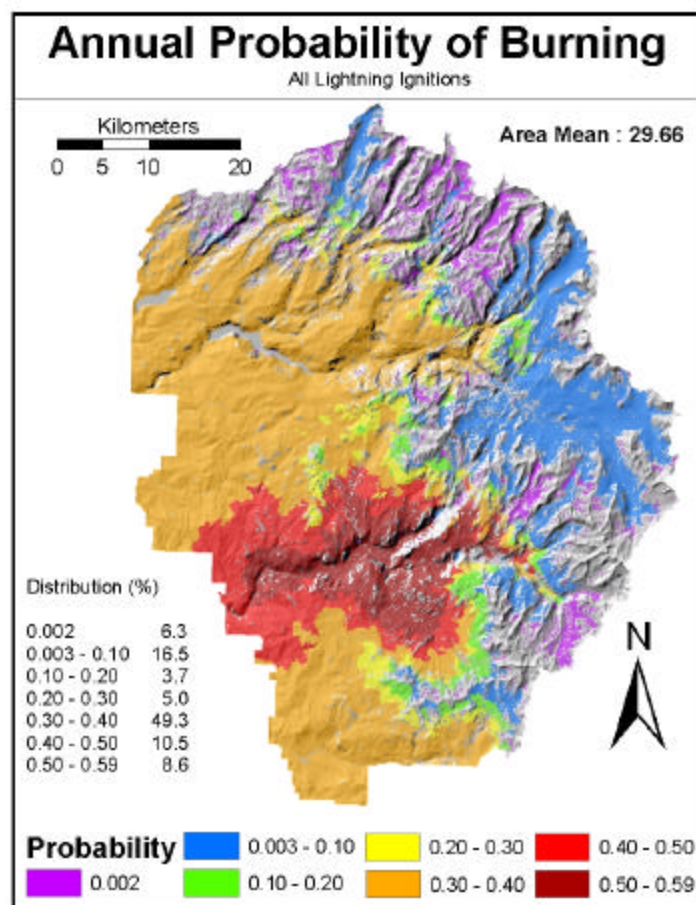
- avgall – this is the main output. It contains the average annual probability of burning values for your study area.
- avg\_<ptile> - these grids contain the probability of burning under the percentile weather category for which they are named. E.g. if your categories are 0-79, 80-89, 90-97 and 98-100 then avg\_100 would contain the probability of burning for the 98-100 category, avg\_97 the probability of burning for the 90-97 category etc.
- avg\_<dir> – these grids contain the probability of burning for a particular wind direction and are named accordingly (e.g. North-avg\_n, Northeast-avg\_ne etc.)

## Interpreting BurnPro Results

The values in BurnPro's output grids represent average annual probability of burning. The probability of any event can range from 0 (certain it won't occur) to 1 (certain it will occur). The numbers output by BurnPro have been converted to percentages and will range from 0.2 to 100%. It is important that these values be

interpreted as *relative* probabilities rather than as absolute probabilities. A value of 20% should not be interpreted as having a one-in-five chance of occurring, but it can be interpreted as being twice as likely as a value 10%. The predictions are based on long-term ignition and weather patterns and therefore should be used for long-term planning efforts rather than being interpreted for short-term purposes. Below is an example of the average annual probability of burning for Yosemite National Park (Figure 14).

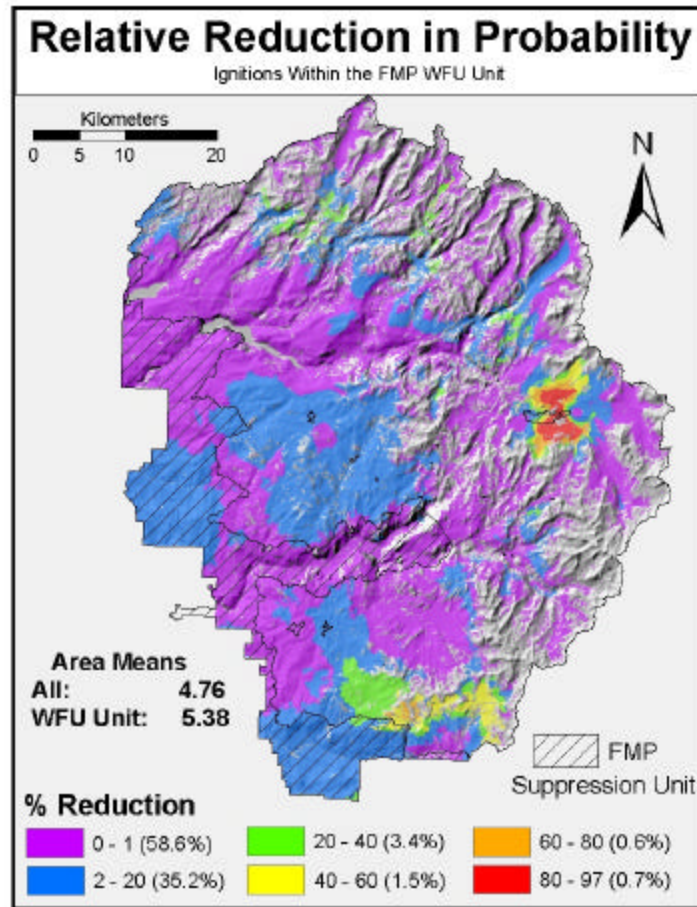
**Figure 14.** Annual probability of burning example.



Where current conditions allow for WFU, results can be evaluated to see if there are sufficient natural ignitions to restore natural fire frequencies. This will help to identify those areas where restoration objectives can be most easily met through

the use of natural ignitions; these areas could be given priority for implementing WFU programs (See Figure 15).

**Figure 15.** Relative reduction in probability of burning example.



This information is also useful in helping to identify areas within candidate WFU zones where the number, location, and timing of natural ignitions are inadequate for restoring fire. In these areas, the use of prescribed fire, or even accidental human-caused ignitions, could be evaluated in light of restoration objectives.

## General Caveats

Any model is merely a simulation of reality and will never be completely accurate. BurnPro is certainly no exception. The following are a few of the caveats to keep in mind when interpreting BurnPro's results.

1. BurnPro's predictions are only as good as the accuracy of the input data. The better (more accurate, longer periods of record etc.) the input data the more accurate the predictions.
2. BurnPro's predictions are based on current fuels. If there is a change in the fuels (e.g. via a fire) predictions will change. What this means is that BurnPro's predictions remain accurate only so long as the underlying data remains the same.
3. The ignition density grids BurnPro uses are developed from the monthly ignition point coverages using the ArcInfo command POINTSTATS. In our implementation, pointstats merely counts the number of points within a particular radius of a grid cell and populates the cell with this data. We then divide this number by the number of years represented by the ignition data to obtain an annual ignition density. We used a search radius of 564.19 meters. This radius was chosen because it results in a search *area* of one square kilometer. The selection of this search radius was a compromise between the following factors: locational inaccuracy of the reported ignition points, short periods of record for ignition data (and therefore low densities) and the minimization of the misleading data generated by large search radii. But, the choice of this particular search radius could be seen as being somewhat arbitrary.
4. HRMAs are calculated based on data developed on flat ground (Anderson, 1983; Fons, 1946), and therefore do not take wind-slope interactions into account.
5. ROS are based on daily averages between ROS at 4am and 2pm. Therefore, the impacts of weather variability at shorter time scales (e.g. a 2 hour wind

event) are not represented by the model. In addition, investigations comparing twice-daily averages to twelve-times-daily averages indicate that twice-daily may slightly over-predict ROS.

6. Probability predictions near the edge of the study area are less accurate than those further in. This is because predictions near the edge don't account for the influence of fires immigrating in from outside the study area.
7. Keep in mind the fact that BurnPro's predictions don't account for any suppression efforts.
8. Weather data is gathered from a RAWS station at a single point (or at a few points if using multiple RAWS) but is applied to a much wider area. Variability in weather conditions over the area are not accounted for.